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First Enantioselective Catalysis using a Helical Diphosphane

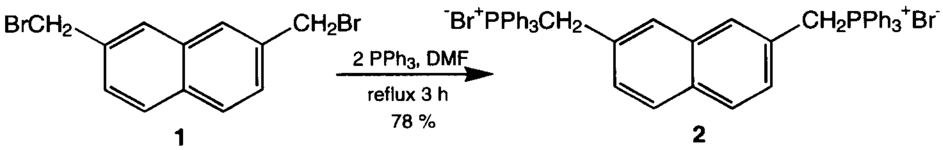
Manfred T. Reetz,* Eckart W. Beuttenmüller and Richard Goddard

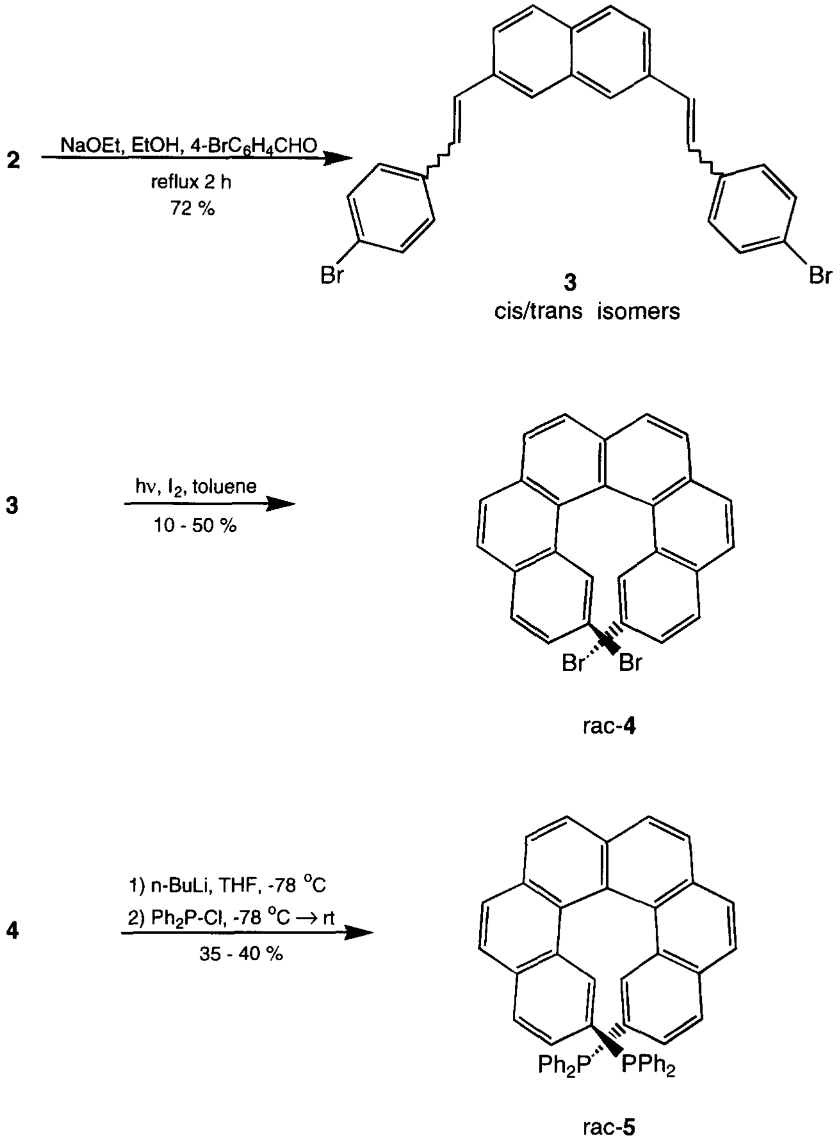
Max-Planck-Institut für Kohlenforschung, Kaiser-Wilhelm-Platz 1, D-45470 Mülheim/Ruhr, Germany

Abstract: The synthesis of 2,15-bis(diphenylphosphino)-hexahelicene (PHelix) in enantiomerically pure form and its use as a helical ligand for enantioselective rhodium-catalyzed hydrogenation are described. © 1997 Elsevier Science Ltd.

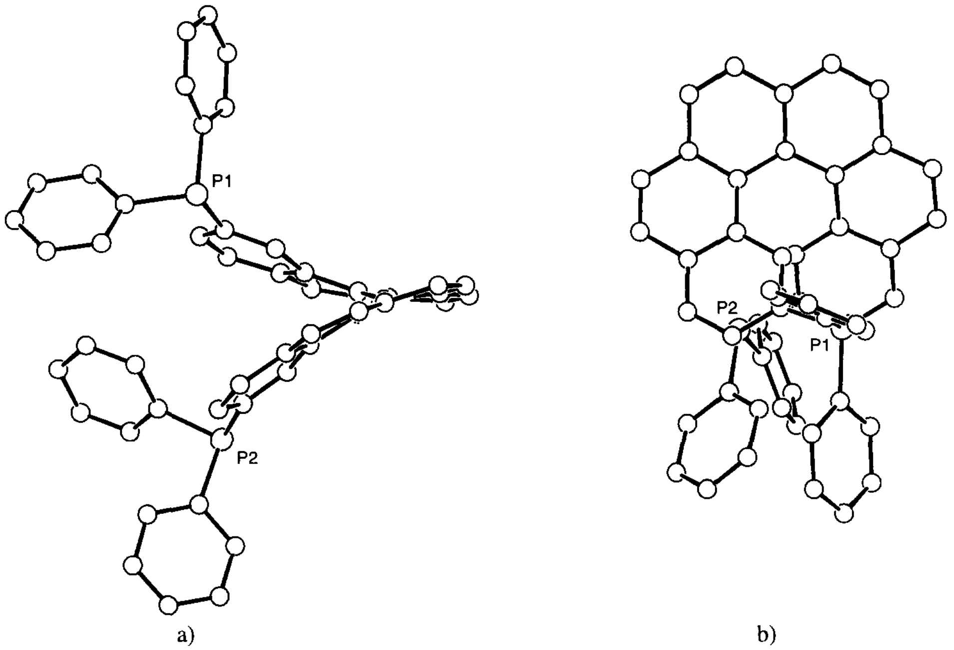
Transition metal catalyzed enantioselective reactions traditionally make use of chiral auxiliaries having central, planar or axial asymmetry.[1] In many cases the chiral auxiliaries are phosphanes, although nitrogen-containing compounds have also emerged as useful ligands.[2] Interestingly, to date no examples of enantioselective catalysis based on helical diphosphanes are known. Recently, Brunner *et al.* reported the synthesis of 2,15-bis(diphenylphosphino)hexahelicene **5** in racemic form.[3] However, the antipode separation required for application of this chiral diphosphane in asymmetric catalysis was not achieved nor were metal complexes prepared.[3] We report here our independent efforts in this novel field, namely the synthesis of **5**, which we call PHelix,[4] its X-ray structural analysis and its antipode separation, as well as the first application in enantioselective metal catalysis.[5]

The key intermediate in our synthesis of rac-**5**, which starts from compound **1**, is the known dibromide rac-**4**,[6] the preparation of which was improved as shown below. Lithiation and reaction with Ph_2PCl then provided rac-**5** in 35 - 40 % yield following chromatography over SiO_2 (pentane/ethyl acetate 5 : 1) and recrystallization from diethyl ether.





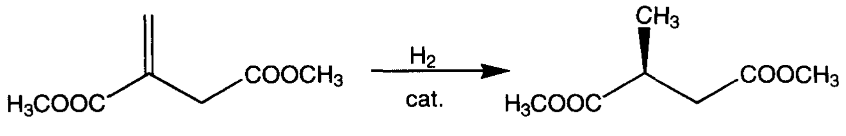
Crystals of rac-**5** were analyzed by X-ray crystallography.[7] Figure 1 shows the twisted helical form of the carbon backbone, which is geometrically quite similar to the structure of hexahelicene itself.[8] The two phosphorus atoms span a distance of 6.481(1) Å [P1···P2], which is much longer than the 4.6 Å predicted on the basis of force field calculations.[3]



a) b)

Fig. 1 Molecular structure of **5**: a) side view; b) top view

Chromatographic resolution of the diphosphane into its enantiomers was difficult because of partial decomposition on the HPLC column. However, the antipode separation of rac-**4** was achieved on a preparative scale by HPLC using a chiral stationary phase (Chiralcel, 20 µm), the mobile phase being n-heptane/2-propanol (99.5 : 0.5). Starting with 203 mg of rac-**4**, a total of 144 mg of pure product was separated, equivalent to a yield of 71 %. 81 mg of (-)- and 63 mg of (+)-2,15-dibromohexahelicene were obtained in >96 % ee. On the basis of a comparison with the sign of the optical rotation of other substituted [6]-helicenes,[9] it may be concluded that (-)-**4** and (+)-**4** possess the helical M and P configurations, respectively. (-)-**4** was subjected to lithiation/phosphinylation, yielding optically active (-)-**5** in essentially enantiomerically pure form (>98 % ee as shown by chiral HPLC analysis). Although the sample contained a small amount of Ph_2PPPh_2 as a side product, it was treated with the stoichiometric amount of $Rh^+(COD)_2BF_4^-$ to form the corresponding complex **5**-$Rh^+(COD)BF_4^-$. This was used *in situ* in a preliminary experiment directed toward testing enantioselective hydrogenation of itaconic acid ester **6**. Hydrogenation was performed at room temperature with 0.1 mol-% of the catalyst in CH_2Cl_2 as solvent and a H_2-pressure of 1 atm. The mixture was worked up and the product **7** analyzed by chiral GC (30 m GTA). 54 % of **7** formed with an enantiomeric excess of 39 % in favor of the S-enantiomer. In view of the nature of the impurity, this value is a lower limit.



6 **7**

In summary, we have demonstrated for the first time the utility of optically active helical diphosphanes in enantioselective transition metal catalysis. Optimization and applications in other catalytic reactions are in progress.

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REFERENCES

1. Brunner, H.; Zettlmeier, W. *Handbook of Enantioselective Catalysis with Transition Metal Compounds*; VCH: Weinheim, 1993; Noyori, R. *Asymmetric Catalysis in Organic Synthesis*; Wiley: New York, 1994.
2. Pfaltz, A. *Acc. Chem. Res.* **1993**, *26*, 339-345.
3. Terfort, A.; Görls, H.; Brunner, H. *Synthesis* **1997**, 79-86.
4. Brunner, *et al.*,[3] have dubbed **5** as [6]-heliphos. However, the term "heliphos" has already been used in conjunction with the tripodal ligand (R),(S)-1,3-bis(diphenylphosphino)-2-(diphenylphosphinomethyl)-1-phenylpropane by S. H. Bergens, as presented at the international meeting ISHC$_{10}$ in Princeton/USA, July 1996.
5. Beuttenmüller, E. W. projected PhD thesis, Universität Bochum, 1997.
6. Yamamoto, K.; Ikeda, T.; Kitsuki, T.; Okamoto, Y.; Chikamatsu, H.; Nakazaki, M. *J. Chem. Soc., Perkin Trans. I* **1990**, 271-276.
7. X-ray analysis of **5** · $C_4H_{10}O$: $C_{54}H_{44}OP_2$, M_r = 770.8 g · mol^{-1}, orange crystals, crystal size 0.39 x 0.49 x 0.70 mm, triclinic, a = 11.213(1), b = 13.745(2), c = 16.121(2) Å, α = 65.46(1), β = 77.76(1), γ = 71.57(1)°, V = 2134.8(5) Å^3, T = 293 K, Z = 2, d_{cal} = 1.20 g · cm^{-3}, μ = 0.14 mm^{-1}, space group $P\bar{1}$ [No. 2], Enraf-Nonius CAD4 diffractometer, λ = 0.71069 Å, ω-2θ-scan, 10068 measured reflections, $[(\sin\theta)/\lambda]_{max}$ = 0.65 Å^{-1}, 9718 independent reflections (R_{av} = 0.02), 6757 observed reflections [$I>2\sigma(I)$], structure solved by direct methods (SHELXS-86, Sheldrick, G. M. *Acta Cryst.* **1990**, *A46*, 467-473), final refinement by least-squares (on F_o^2, SHELXL-93, Sheldrick, G. M., University of Göttingen, 1993), H riding, R = 0.064 (obs. data), wR = 0.187 for 489 refined parameters [$w = 1/(\sigma^2(F_o^2) + (0.113P)^2 + 0.8731P)$, where $P = (F_o^2+2F_c^2)/3$], S = 1.03, final shift/error 0.001, residual electron density 0.70 eÅ^{-3}. Atomic coordinates and e.s.d.'s have been deposited at the Cambridge Crystallographic Data Centre.
8. de Rango, C.; Tsoucaris, G.; Declerq, J. P.; Germain, G.; Putzeys, J. P. *Cryst. Struct. Commun.* **1973,** *2*, 189-192.
9. Laarhoven, W. H.; Prinsen, W. J. C. *Top. Curr. Chem.* **1984**, *125* (Stereochemistry), 63-130.

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